Missouri
Department of
Natural Resources

Appendix E - Off-Road

- Off-road Mobile Source
- Non-road Emissions Table
- Emissions Totals by County and Pollutant

1 OFF-ROAD MOBILE SOURCE

Off-road emissions result from the use of fuel in a diverse collection of vehicles and equipment, including vehicles and equipment such as recreational vehicles, logging equipment, agricultural equipment, construction equipment, industrial equipment, residential and commercial lawn and garden equipment, recreational and commercial marine vessels, locomotive equipment, and aircraft. The 1999 off-road mobile emissions were to be estimated by the Environmental Protection Agency (EPA). The draft off-road emissions for Commercial Marine Vessels were 37.11 tons of NOx. This number was believed to be high for this category. Therefore, the state of Missouri was to explore other methodologies that can be used to estimate this source category. Below is a brief description of the methodology used in the Kansas City Maintenance Area Emissions Inventory and which is believed to be an appropriate methodology to estimate Commercial Marine Vessels emissions in the St. Louis Non-attainment Area.

1.1 Commercial Marine Vessels

1.1.1 Estimation Methodology and Data

Emissions from commercial marine vessels were calculated based on the tonnage of cargo moved by ships along the Mississippi River and Missouri River through the port of St. Louis City, Missouri.

The equations used in the calculations were taken from *Commercial Marine Emissions Inventory for EPA Category 2 and 3 Compression Ignition Marine Engines in the United States Continental and Inland Waterways* (1). The equations are summarized below.

First, annual cargo movement in ton-miles was calculated by multiplying the number of tons shipped in 1999 along the Mississippi River and Missouri River through port of St. Louis City, Missouri, by the length of the portion of the Mississippi River and Missouri River running through the eight-county St. Louis City maintenance area.

$$C = L \times T$$

Where:

C = Annual cargo movement (ton-miles)
L = Length of Mississippi & Missouri rivers through St. Louis Non-attainment Area (miles)
T = Total amount of cargo shipped through the St. Louis Non-attainment Area in 1999 (short tons)

Emissions per ton-mile were calculated by dividing the product of the deadweight tonnage, cargo capacity factor, and average vehicle speed. Deadweight tonnage is a measurement of the total contents of a ship, including cargo, fuel, crew, passengers, food, and water aside from boiler water. The cargo capacity factor is applied as a correction because ships do not typically operate fully loaded with cargo.

$$E_{TM} = E_{\mathbf{d}} \div (DWT \times CCF \times V \times 24)$$

Where:

E_{TM} = Emissions per ton-mile (lbs/ton-mile)
E_d = Emissions per day per ship from Method A (lbs/day/ship)
DWT = Average dead weight tonnage per ship (tons/ship)
CCF = Cargo capacity factor
V = Average speed of vessel across duty cycle adjusted for max. BHP (miles/hour)
24 = Hours per day to convert ship speed to ship miles per day

Emissions per year were calculated by multiplying the results from the previous equations.

$$E_Y = E_{TM} \times C$$

Where:

E_Y = Emissions per year (lb/year)
E_{TM} = Emissions per ton-mile (lbs/ton-mile)
C = Annual cargo movement (ton-miles)

The total tonnage of cargo shipped along the Mississippi River and Missouri River through the port of St. Louis City, Missouri, in 1999 were 32,650,783 and 1,488,000 short tons, respectively, obtained from the U.S. Army Corps of Engineers Waterborne Commerce Statistics Center (2). From reference 1, the following values were obtained:

- Average emissions per day per ship on inland rivers: 1,640.52 lbs NOx/day-ship, 59.54 lbs HC/day-ship
- Cargo capacity of ships on inland rivers: 0.6
- Average deadweight tonnage per ship: 15,454 short tons
- Average speed of vessels on inland rivers: 8.18 mph

Emissions were apportioned to the county level based on the percent of the Mississippi River and Missouri River flowing adjacent to/through each county. It was assumed that 50% of emissions from Mississippi River would be accounted for in Illinois' inventory (Madison, Monroe, and St. Clair counties) and the other 50% of emissions would go to Missouri's inventory (Jefferson, St. Louis, St. Louis City, and St. Charles counties). Using ArcView, the length of the Mississippi River running through the entire seven-county St. Louis City maintenance area is calculated to be 96.47 miles. 21.41 miles runs along Jefferson County, 13.97 miles runs along St. Louis County, 19.72 miles runs along St. Louis City and 41.36 miles runs along St. Charles county. The length of Missouri River going through St. Louis, St. Charles, Franklin and Warren counties is 84.5 miles. Note that emissions from Warren County's emissions were subtracted from the total emissions since it is not a part the non-attainment area. Emissions from Warren County were calculated for the sole purpose of apportioning emissions to the county level.

Hydrocarbons were converted to VOCs by multiplying the hydrocarbon emissions by 1.053, which is the HC to VOC conversion factor for diesel engines used in EPA's NONROAD model (3).

There is no reference that asserts the seasonal or temporal variation for this activity. Therefore, it was assumed that activity does not vary throughout the year and occurs seven days per week.

1.1.2 Emissions Projections

2000, 2007, and 2014 emissions were projected based on BLS growth factors for SCC 2280000000.

County	2000	2007	2014
Franklin	1.0324	1.2039	1.3754
Jefferson	1.0324	1.2039	1.3754
St. Charles	1.0324	1.2039	1.3754
St. Louis	1.0324	1.2039	1.3754
St. Louis City	1.0324	1.2039	1.3754

1.1.3 Sample Calculation

1999 NOx Emissions from Commercial Marine Vessels in Jefferson County

Cargo movement in 1999 = (Length of river through KCMA) x (Total tons shipped through KCMA in 1999)
= (96.47 miles) x (32,650,783 tons)
= 3,149,821,036.01 ton-miles

Emissions per ton-mile = (Emissions/day-ship)/[(Avg. deadweight tonnage) x (cargo capacity factor) x (Avg. speed)]
= (1,640.52 lbs/NOx/day-ship) / [(15,454 tons/ship) x (0.6) x (8.18 miles/hr) x (24 hrs/1 day)]
= 9.01053×10^{-4} lbs NOx/ton-mile

1999 SLCMA annual emissions = (Ton-miles per year) x (Emissions per ton-mile)
= (3,149,821,036.01 ton-miles) x (9.01053×10^{-4} lbs/ton-mile) x (1 ton/2,000 lbs)
= 1419.08 tons NOx/yr

1999 Jefferson co. emissions = (Annual SLCMA emissions) x (Percent of River going through Missouri Counties) x [(Mississippi River in Jefferson. Co)/(Mississippi River in SLCMA)]
= (1419.52 tons NOx/yr) x 0.50 x [(21.41 miles)/(96.47 miles)]
= 161.81 tons NOx/yr

1999 OSD emissions = (161.81 tons NOx/yr) x (2,000 lbs/1 ton) x (1 yr/365 days)
= 862.86 lbs NOx/OSD

1.1.4 Results

Table 6-3 summarizes 1999 and 2012 VOC, NOx, and CO emissions from commercial marine vessels in all counties.

Table 1.1.4.1: Commercial Marine Vessel Emissions in St. Louis Area

County	River Length (mile)	VOC Emissions OSD[1] (Lb/Day)	NOx Emissions OSD[1] (Lb/Day)
Franklin	36.50	2.56	67.04
Jefferson	21.41	32.97	862.86
St. Charles	41.36	68.13	1,782.77
St. Louis	13.97	24.47	640.34
St. Louis City	19.72	30.37	794.84

[1]Ozone Season Day

Table 1.1.4.2: Commercial Marine Vessel Projected Emissions

County	2000		2007		2014	
	VOC	NOx	VOC	NOx	VOC	NOx
Franklin	2.64	69.21	3.08	80.71	3.52	92.21
Jefferson	34.04	890.81	39.70	1,038.81	45.35	1,186.81
St. Charles	70.33	1,840.54	82.02	2,146.32	93.70	2,452.10
St. Louis	25.26	661.09	29.46	770.92	33.66	880.75
St. Louis City	31.36	820.59	36.57	956.93	41.78	1,093.26

1. *Commercial Marine Emissions Inventory for EPA Category 2 and 3 Compression Ignition Marine Engines in the United States Continental and Inland Waterways*, US EPA, EPA 420-R-98-020, August 1998. (http://www.epa.gov/otaq/regs/nonroad/marine/ci/fr/r98020.pdf)

2. "Tonnage for Selected U.S. Ports in 1999" table from U.S. Army Corps of Engineers Waterborne Commerce Statistics Center. (http://www.wrsc.usace.army.mil/ndc/portsname.htm)

3. Conversion Factors for Hydrocarbon Emission Components, Lindhjem, C., US Environmental Protection Agency, Office of Mobile Sources, Report No. NR-002, Nov. 24, 1997.

Return to Appendix

NONROAD Emissions Summary St. Louis MO

2000 Source Category	VOC	NOx
NONROAD Model	38.58	55.57
Aircraft, CMV, Locomotive	2.01	17.59
Totals	**40.59**	**73.16**

2004 Source Category	VOC	NOx
NONROAD Model	32.35	53.39
Aircraft, CMV, Locomotive	2.18	16.01
Totals	**34.526**	**69.40**

2007 Source Category	VOC	NOx
NONROAD Model	25.65	51.07
Aircraft, CMV, Locomotive	2.26	14.94
Totals	**27.91**	**66.01**

2014 Source Category	VOC	NOx
NONROAD Model	21.79	45.46
Aircraft, CMV, Locomotive	2.49	13.38
Totals	**24.28**	**58.84**

*emissions tons/avg summer day

Return to Appendix

Emission Totals by County and Pollutant

All Fuels **Tons/Day**

NONROAD EMISSIONS FOR MO SIDE OF ST. LOUIS NA
STAGE II 97%, rvp 6.7, GS .0303, 0 2.1, DS 0.5

Typical weekday for Summer Season, 2000

Date of Model Run: Aug 28 16:45:47: 2002 Today's Date: 8/28/2002

County	Exhaust VOC	Exhaust NOx	Exhaust CO	Exhaust PM10	Exhaust SOx	Exhaust CO2
Franklin County	1.26	3.91	16.85	0.38	1.33	319.46
Jefferson County	2.03	4.02	29.18	0.48	1.53	365.44
St Charles County	4.44	10.71	58.28	1.22	3.98	929.62
St Louis City County	4.09	4.99	77.68	0.55	1.43	504.23
St Louis County	21.86	31.94	345.99	3.97	11.42	3,102.40
Totals:	**33.67**	**55.57**	**527.99**	**6.59**	**19.69**	**5,221.16**

Emission Totals by County and Pollutant

All Fuels **Tons/Day**

NONROAD EMISSIONS FOR MO SIDE OF ST. LOUIS NA
STAGE II 97%, rvp 6.7, GS .0303, 0 2.1, DS 0.5

Typical weekday for Summer Season, 2000

Date of Model Run: Aug 28 16:45:47: 2002 Today's Date: 8/28/2002

County	Crankcase VOC	Diurnal VOC	Vapor Displacement VOC	Spillage VOC	Total VOC
Franklin County	0.04	0.08	0.00	0.07	1.45
Jefferson County	0.05	0.10	0.00	0.16	2.34
St Charles County	0.10	0.18	0.00	0.32	5.04
St Louis City County	0.15	0.17	0.00	0.32	4.74
St Louis County	0.53	0.49	0.01	2.13	25.01
Totals:	**0.87**	**1.02**	**0.02**	**3.01**	**38.58**

Emission Totals by County and Pollutant

All Fuels **Tons/Day**

NONROAD EMISSIONS FOR MO SIDE OF ST. LOUIS NA
STAGE II 97%, rvp 6.8, GS .0303, O 2.1, DS 0.5

Typical weekday for Summer Season, 2004

Date of Model Run: Aug 28 16:31:06: 2002 Today's Date: 8/28/2002

County	Exhaust VOC	Exhaust NOx	Exhaust CO	Exhaust PM10	Exhaust SOx	Exhaust CO2
Franklin County	1.04	3.70	17.60	0.35	1.50	354.84
Jefferson County	1.66	3.78	30.87	0.45	1.75	405.35
St Charles County	3.59	9.98	61.52	1.12	4.52	1,032.59
St Louis City County	3.52	5.21	84.37	0.59	1.70	564.41
St Louis County	17.92	30.73	372.14	3.80	13.15	3,450.50
Totals:	**27.73**	**53.39**	**566.50**	**6.31**	**22.62**	**5,807.68**

Emission Totals by County and Pollutant

All Fuels **Tons/Day**

NONROAD EMISSIONS FOR MO SIDE OF ST. LOUIS NA
STAGE II 97%, rvp 6.8, GS .0303, O 2.1, DS 0.5

Typical weekday for Summer Season, 2004

Date of Model Run: Aug 28 16:31:06: 2002 Today's Date: 8/28/2002

County	Crankcase VOC	Diurnal VOC	Vapor Displacement VOC	Spillage VOC	Total VOC
Franklin County	0.03	0.09	0.00	0.07	1.22
Jefferson County	0.03	0.11	0.00	0.16	1.96
St Charles County	0.07	0.20	0.00	0.31	4.17
St Louis City County	0.08	0.19	0.00	0.31	4.11
St Louis County	0.34	0.54	0.01	2.07	20.89
Totals:	**0.55**	**1.13**	**0.02**	**2.93**	**32.35**

Emission Totals by County and Pollutant

All Fuels **Tons/Day**

NONROAD EMISSIONS FOR MO SIDE OF ST. LOUIS NA
STAGE II 97%, rvp 6.8, GS .0087, 0 2.1, DS 0.5

Typical weekday for Summer Season, 2007

Date of Model Run: Aug 28 17:01:29: 2002 Today's Date: 8/28/2002

County	Exhaust VOC	Exhaust NOx	Exhaust CO	Exhaust PM10	Exhaust SOx	Exhaust CO2
Franklin County	0.85	3.46	18.55	0.34	1.62	381.70
Jefferson County	1.31	3.53	32.70	0.44	1.89	436.20
St Charles County	2.78	9.25	65.05	1.09	4.89	1,111.61
St Louis City County	2.75	5.32	90.79	0.61	1.86	609.45
St Louis County	13.53	29.50	396.73	3.80	14.27	3,717.80
Totals:	**21.22**	**51.07**	**603.81**	**6.28**	**24.53**	**6,256.75**

Emission Totals by County and Pollutant

All Fuels **Tons/Day**

NONROAD EMISSIONS FOR MO SIDE OF ST. LOUIS NA
STAGE II 97%, rvp 6.8, GS .0087, 0 2.1, DS 0.5

Typical weekday for Summer Season, 2007

Date of Model Run: Aug 28 17:01:29: 2002 Today's Date: 8/28/2002

County	Crankcase VOC	Diurnal VOC	Vapor Displacement VOC	Spillage VOC	Total VOC
Franklin County	0.02	0.09	0.00	0.06	1.03
Jefferson County	0.03	0.11	0.00	0.15	1.60
St Charles County	0.06	0.20	0.00	0.29	3.34
St Louis City County	0.07	0.20	0.00	0.29	3.32
St Louis County	0.31	0.58	0.01	1.93	16.36
Totals:	**0.49**	**1.19**	**0.02**	**2.73**	**25.65**

Emission Totals by County and Pollutant

All Fuels **Tons/Day**

NONROAD EMISSIONS FOR MO SIDE OF ST. LOUIS NA
STAGE II 97%, RVP 6.8, GS .008, 0 2.1, DS 0.5

Typical weekday for Summer Season, 2014

Date of Model Run: Aug 28 17:10:50: 2002 Today's Date: 8/28/2002

County	Exhaust VOC	Exhaust NOx	Exhaust CO	Exhaust PM10	Exhaust SOx	Exhaust CO2
Franklin County	0.67	2.93	20.79	0.36	1.92	445.73
Jefferson County	1.05	2.96	36.98	0.48	2.26	510.85
St Charles County	2.18	7.60	73.60	1.16	5.80	1,302.63
St Louis City County	2.25	5.48	104.92	0.69	2.28	720.26
St Louis County	10.91	26.48	453.40	4.17	17.20	4,381.35
Totals:	**17.05**	**45.46**	**689.67**	**6.86**	**29.46**	**7,360.82**

Emission Totals by County and Pollutant

All Fuels **Tons/Day**

NONROAD EMISSIONS FOR MO SIDE OF ST. LOUIS NA
STAGE II 97%, RVP 6.8, GS .008, 0 2.1, DS 0.5

Typical weekday for Summer Season, 2014

Date of Model Run: Aug 28 17:10:50: 2002 Today's Date: 8/28/2002

County	Crankcase VOC	Diurnal VOC	Vapor Displacement VOC	Spillage VOC	Total VOC
Franklin County	0.02	0.10	0.00	0.07	0.86
Jefferson County	0.02	0.12	0.00	0.16	1.35
St Charles County	0.05	0.22	0.00	0.32	2.77
St Louis City County	0.06	0.23	0.00	0.31	2.86
St Louis County	0.30	0.65	0.01	2.09	13.95
Totals:	**0.46**	**1.33**	**0.02**	**2.94**	**21.79**

Return to Appendix